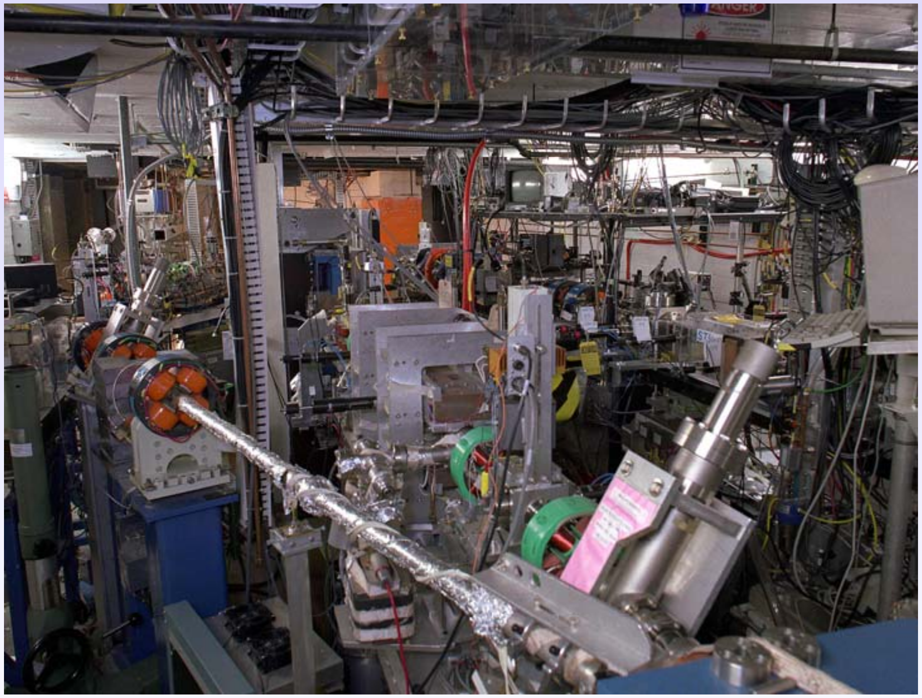
BNL Accelerator Test Facility - ATF

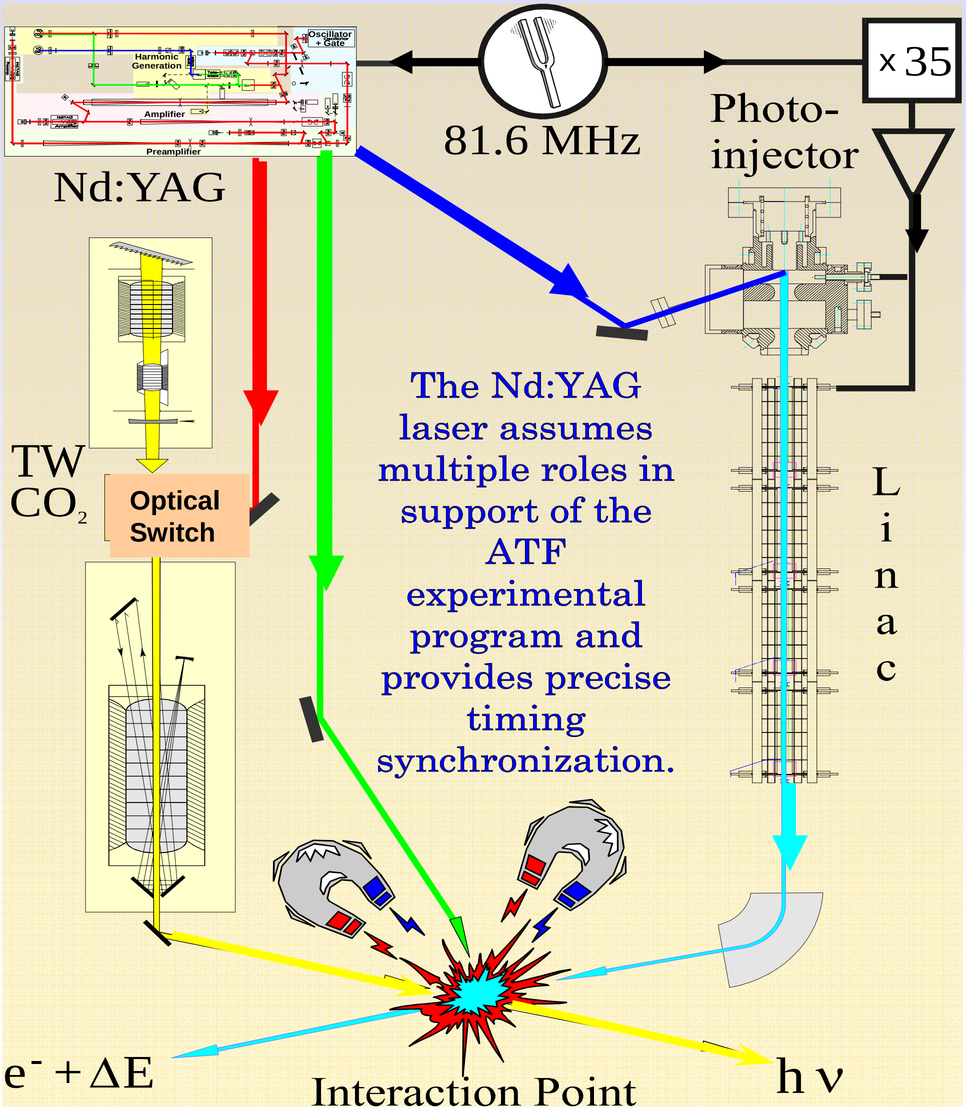
- The ATF is a proposal-driven, advisory committee reviewed USER FACILITY for long-term R&D of the Physics of Beams.
- The ATF features:
  - High brightness electron gun (World record in beam brightness)
  - 75 MeV Linac
  - level High-power lasers beam-synchronized at a picosec
  - 4 beam lines + controls
- The ATF community consists of National Labs, universities, industry and international collaborations.
  - ATF contributes to Education in Beam Physics. **(~2 PhDs/year)**
- In-house R&D on photoinjectors, lasers, diagnostics, computer control sys. and more **(~3 Phys. Rev. X/year)**
- Support from HEP and BES.



ATF: A Unique resource world-wide in the comprehensive nature of the facilities

ATF Subsystems Architecture

- ATF's laser & accelerator complex currently serves 13 approved experiments
- High power Nd:YAG laser and unique Terawatt CO2 laser
- Nd:YAG drive laser provides short, high power optical pulses for generating electron bunches in RF photoinjector and "slicing" of CO2 laser
- Precise and reliable optical synchronization allows sub-ps control at experimental interaction point



Experiments

5 active experiments

- A SASE-Free Electron Laser Experiment, VISA, at the ATF Linac, **UCLA**
- Structure-based Laser Driven Acceleration in a Vacuum, **National Tsinghua Univ., BNL**
- Photocathode R&D, **BNL**
- Electron Beam Pulse Compression Based Physics at the ATF, **UCLA**
- Study of Compton Scattering of Picosecond Electron and CO2 Beams **Tokyo Metropolitan U, Waseda U, KEK, Princeton U**

Feasibility studies and LDRD

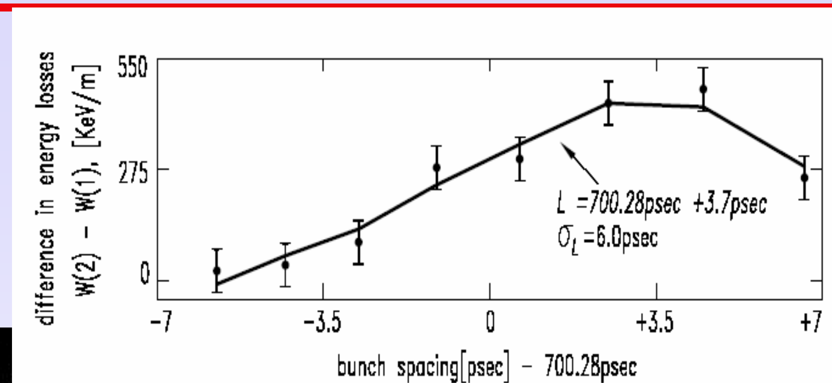
- **Stony Brook Univ.** : X-ray generation from target
- **Kyushu Univ.**: CO2 Laser induced EUV
- **Univ. of Texas**: Application of thin SiC films to sub-wavelength lithography and compact particle acceleration
- **RHIC/BNL**: Magnetized beam transport
- **LDRD**: Optical stochastic cooling of Gold ion beams in RHIC

6 experiments scheduled to start in 2005

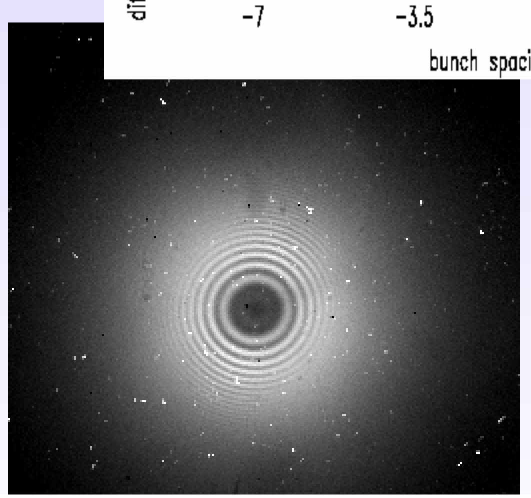
- Ultra-fast Detection of Relativistic Charged Particles by Optical Techniques, **BNL, Montclair State University, Univ. of Pittsburgh**
- Laser Driven Cyclotron Autoresonance Accelerator, **Omega-P/Yale**
- Particle Acceleration by Stimulated Emission of Radiation (PASER), **Technion, Israel.**
- Multi-bunch Plasma Wakefield Acceleration at ATF, **Univ. Southern California**
- Laser Wakefield Acceleration Driven by a CO2 Laser, **STI Optronics**
- Emittance Optimization Using Active Transverse Laser Shaping, **Duke Univ.**

Recent Results (3 completed experiments, 2 PhD)

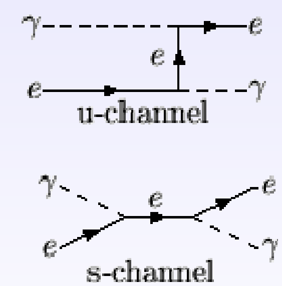
- Stimulated Dielectric Wakefield Accelerator. Omega-P Inc., Yale University, Columbia University. (Completed in July 2004; PhD: October 2004)



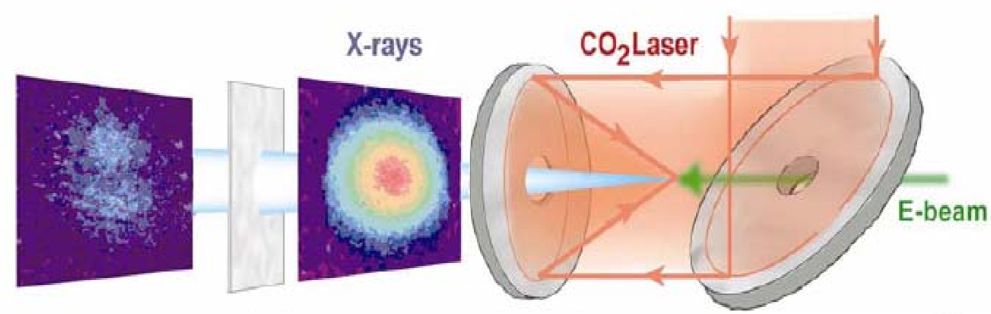
- Optical Diffraction-Transition Radiation Interferometry Diagnostics for Low Emittance Beams, TR Research Inc. U Maryland (Completed in January 2005)



Linear Compton



- Nonlinear Compton Scattering, Tokyo Metropolitan U, Waseda U, KEK, Princeton U, UCLA (Completed in January 2005; PhD: March 2005)
First experiment with new terawatt CO2 laser!



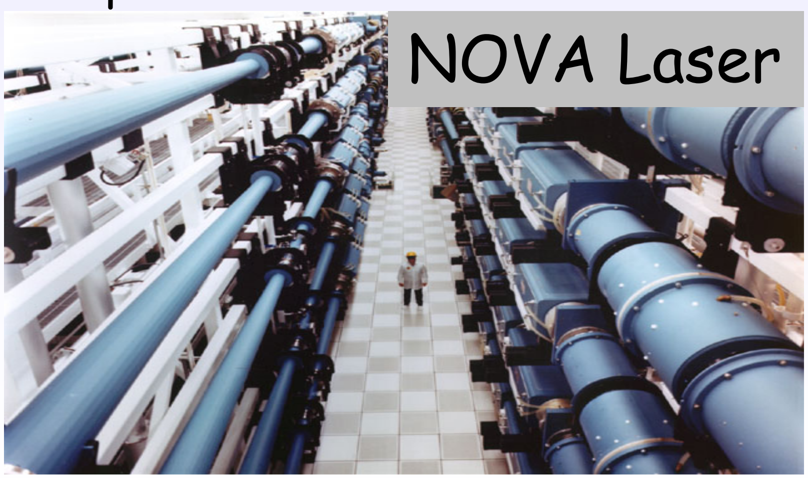
Ultra-fast CO2 laser technology opens new prospects for laser-driven ion sources

Electron interacting with a strong EM wave acquires energy $W = mc^2 a^2 / 2$

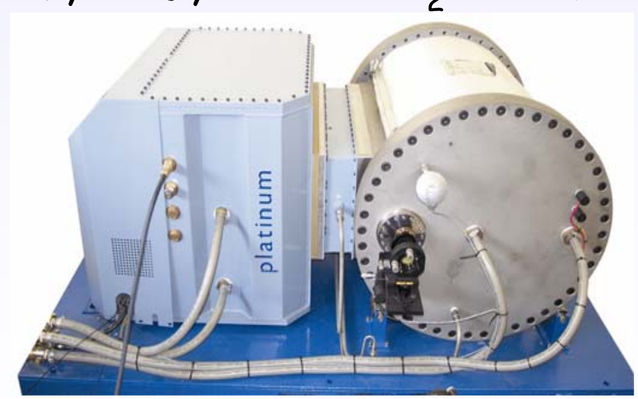
where $a = eE / m\omega c$ - dimensionless laser strength parameter.

Thus, CO_2 laser (λ=10 μm) produces 100 times higher particle yield per 1 Joule to compare with presently used solid state lasers ($\lambda \approx$1 μm) provided that a threshold condition $P_L \times \lambda^2 \geq 100 \left[TW \times \mu m^2 \right]$ is reached.

A PW, kJ solid state laser delivering one shot per several hours…..

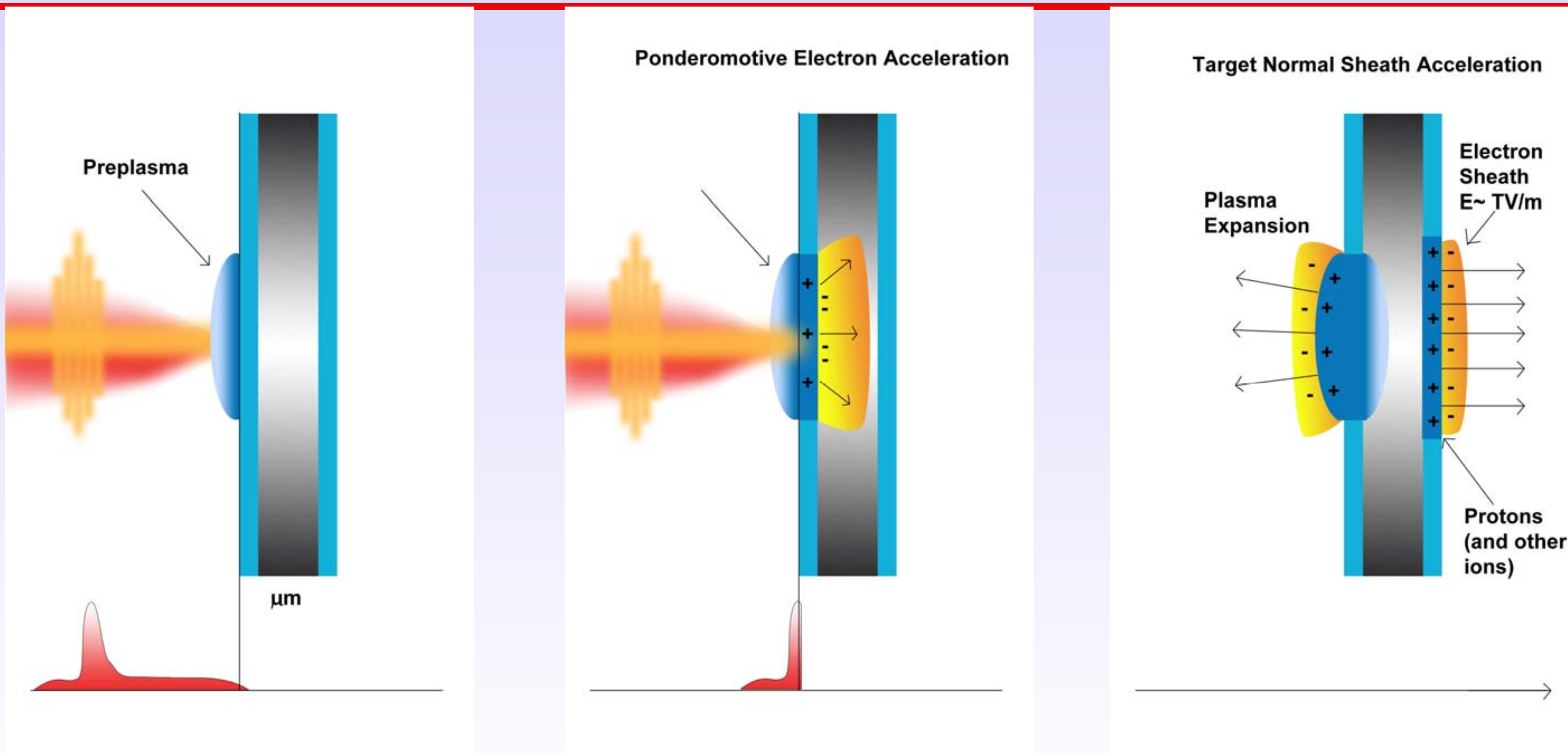


…..can be replaced with a compact TW, 10 J, 10 Hz CO_2 laser.



60 cm

Ion acceleration mechanism



Broad energy spectrum (protons >50MeV, ions >8MeV/nucleon); high brightness (>10^{12} protons/pulse, ε_N<0.005 mm mrad; Cowan et al PRL 2004)

Optical Stochastic Cooling for RHIC

Microwave [λ=50 mm] Optical [λ=10 μm]

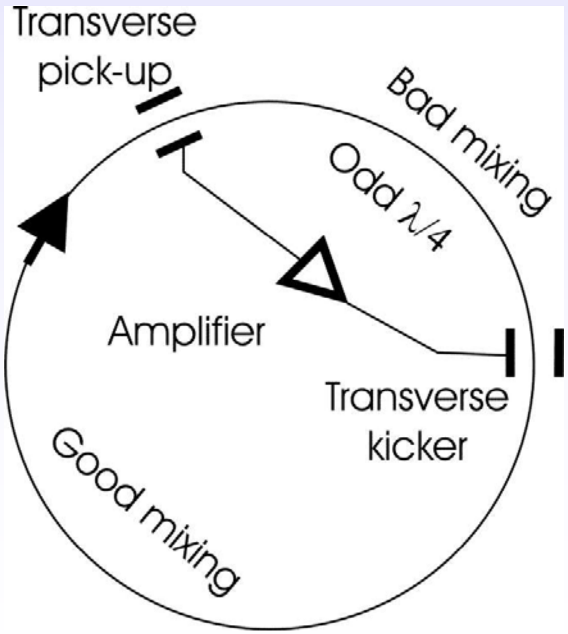
$$n_d^{ideal} \approx N_s$$

$$N_s = \frac{\lambda}{3\Gamma}\frac{N_i}{\sigma_l}$$

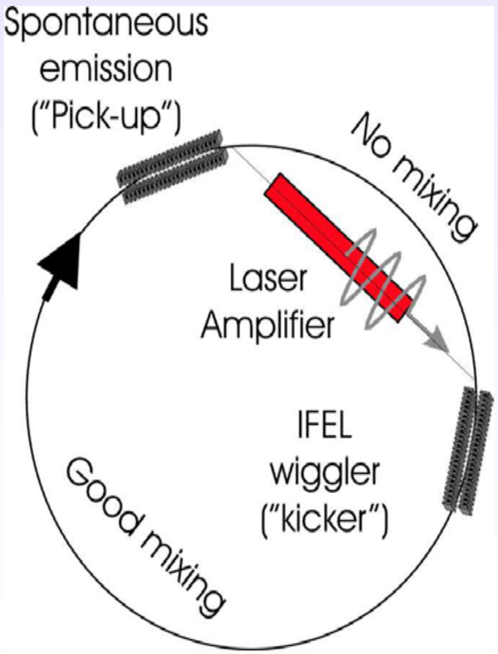
$$n_d \approx 2eN_s$$

e=2.7182…

Nobel prize in 1984

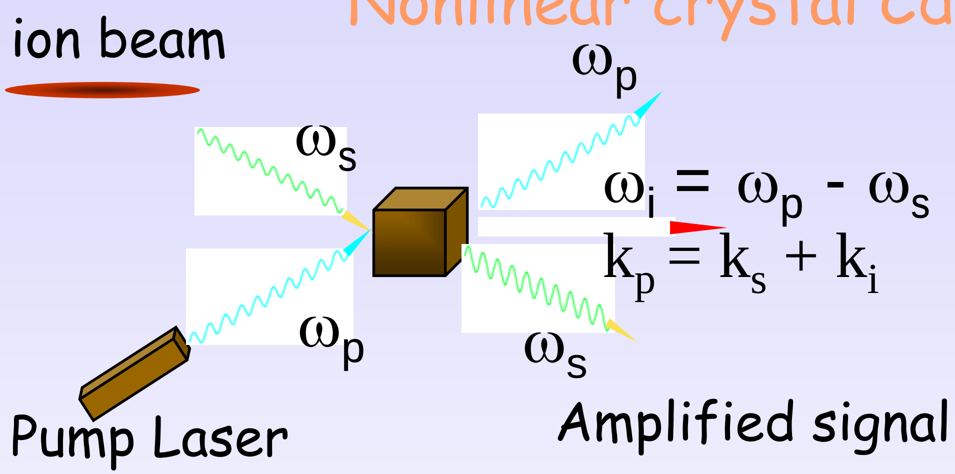


- 16 s cooling time with unlimited laser power.
- In practice, cooling time is limited by the laser amplifier.
- ~1 hr with 16 W

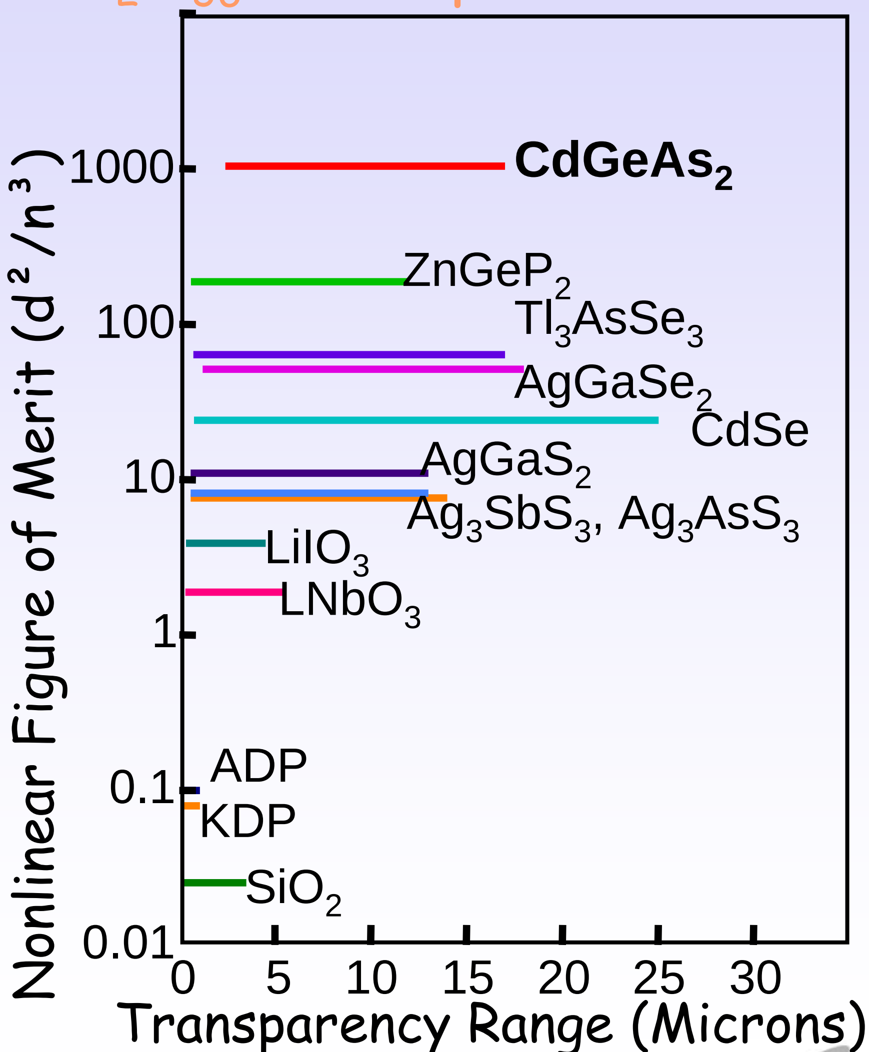


Broadband CW Parametric Amplifier

Nonlinear crystal $CdGeAs_2$ d_{36} = 236 pm/V



λ_{pump} = 5.3 µm (Doubled frequency CO_2 laser)
λ_{signal} = 12 µm
P_L = 20 MW/cm^2 (damage threshold, conservative)
l = 4 mm (*e* times gain length)
3 cm length crystal →
intensity gain 3 10^5



Current status of OSC for RHIC

Colors/bullets:

- ➢ Scientific research
- ❑ Engineering design
- ❖ Economical optimization

Optical amplifier

- ➢ Gain length (done)
- ➢ Bandwidth (done)
- ➢ Phase fidelity (close)
- ❑ High average power handling
- ❑ Stabilized optical transport line

Mode-locked pump source

- ❑ Collaboration with FIAN
- ❑ CRDF proposal

Lattice

- ➢ Design (test at LBL)
- ➢ Tune diagnostics
- ❖ RHIC lattice design

High field wigglers

- 10T in the proposal
- ❑ 15T state of the art (2 times shorter cooling time)
- ❖ 20T today optimists (4 times shorter cooling time)

ATF Budget Analysis: FY03/07 ($K)

PROJECT	FY03	FY04	FY05	FY06	FY07(req)
• ATF Ops	$ 1,680	$ 1,800	$ 1,800	$ 1,910	$ 2,025
• ATF Equ	$ 200	$ 200	$ 200	$ 130	$ 130
• ATF (BES)	$ 500	$ 500	$ 500	$ 500	$ 500(??)
Totals:	$ 2,380	$ 2,500	$ 2,500	$ 2,540	$ 2,655
FTE's	7.5	8.3	8.5	9.0	9.0

ATF BR KA 1501020

BES BR KC 0204011

ATF unique equipment and expertise can be utilized more efficiently with small staff increase

n.b. Proposal has been submitted to NP for FY06-FY08

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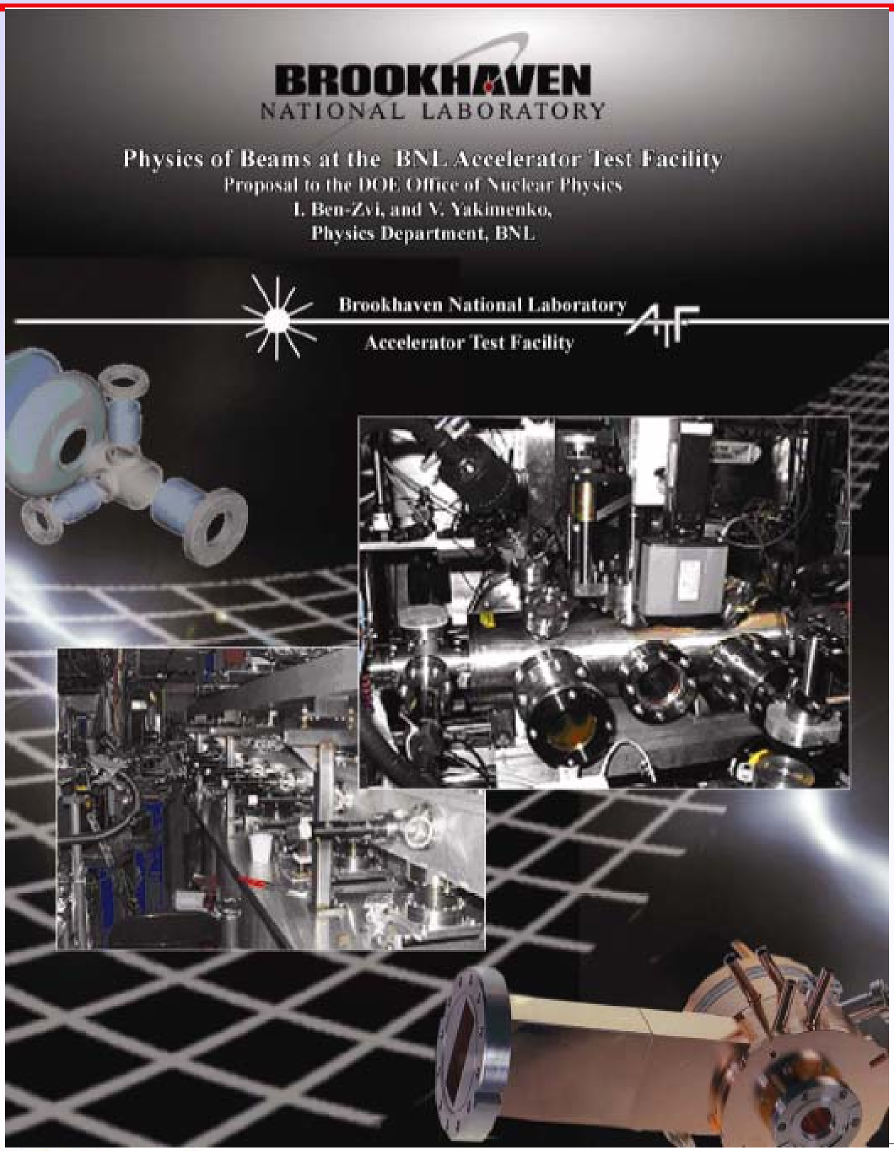

Proposal has been submitted to NP for FY06-FY08 for $350k/year to support R&D toward laser based ultra high brightness proton/ion source and optical stochastic cooling of Gold ion beams in RHIC.